Workshop W4 – FRP Composite Bridge Materials: Design, Build, Strengthen
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Gaylord National Resort & Convention Center, National Harbor, MD
Tuesday, June 12, 2018 - 1:00 – 4:30 p.m. Room Magnolia 1

Rehabilitation of East Lynn Lake Bridge, WV

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Acknowledgement

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- Workforce support from East Lynn Lake Management and USACE Huntington District is greatly appreciated.

Introduction to Polymer Composites

- **Composite:**

  - A heterogeneous combination of two or more materials

  - reinforcing elements such as fibers, fillers
  - binders such as resins or polymers

  - These materials differ in form or composition on a macroscale

  - There exists interface between these materials - compatibility

- **Fiber:**

  - Load-bearing component

- **Resin:**

  - Dissipate loads to the fiber network
  - Maintain fiber orientation
  - Protect the fiber network from damaging environmental conditions such as humidity and high temperature
  - Dictates the process and processing conditions

Fiber Reinforced Polymer (FRP) Composite Advantages

- Superior corrosion resistance
- Excellent thermo-mechanical properties
- High strength-to-weight ratio
- Nonmagnetic
- Cost effectiveness
- Greener in terms of embodied energy
- Many others

Overview of East Lynn Lake Bridge, WV - Steel H-pile Rehab with Composites Project

BRIDGE DATA

Built in 1969, Length – 126’6”, 5 spans, 2 lanes, continuous reinforced concrete slab, H-15-44 loading.

PROBLEM

Corrosion of H-piles resulted in section loss up to **50%,** load rating of **6 tons**, speed reduction to 10 MPH, and one lane closure.

SOLUTION

Advanced FRP composite materials were used to bring the bridge back to original design capacity at **25%** of conventional construction cost in **3 weeks** (March 2014)

PARTNERSHIP

WVU-CFC, USACE Huntington District and USACE ERDC, NSF, FHWA

Comprehensive Composite Approach

1) Polymer concrete as a foundation barrier where FRP shells and SCC concrete rest on;
2) Glass fiber reinforced polymer (GFRP) composite shells/jackets of 20” in diameter to enclose steel piles;
3) Self-consolidated concrete within the shell surrounding H-piles;
4) Glass FRP fabric wrap over FRP shell.

East Lynn Bridge, WV
Before Rehab

Selection of Materials and Design of Field Implementation Methodology

- Systematic evaluation
  - Selection and testing of various materials
  - Design computations
  - Development of a field implementation plan and procedure
- Design/strength computations
  - Tensile strength of the FRP shell both in longitudinal and circumferential directions
  - 28 days compression strength of SCC
  - Consideration of effective areas of H-pile, SCC, and FRP shell to compute column strength by properly accounting for confinement stress of confinement concrete, un-corroded H-pile area and FRP shell area
  - Application of LRFD equations for strength, stiffness and buckling computations

Material Properties Used in East Lynn Bridge Repair

- **SCC Concrete:**
  - Concrete Cylinders (14 days strength): 2760 psi, 2800 psi, 2844 psi (Avg. 2801 psi)
  - Concrete Cylinders (28 days strength): 3100 psi, 3103 psi, 2948 psi (Avg. 3050 psi)

- **FRP Jacket/Shell with Glass Strand Mat (Surrounding/housing SCC Concrete):**
  - Tensile stress (hoop direction): 13.7 ksi
  - Tensile stress (longitudinal direction): 15.4 ksi

- **AQUAWRAP FRP Wrap with Bi-directional Glass Fabric (Outermost 2 layers):**
  - Tensile stress (hoop direction): 40.7 ksi

Step 1: Excavating for Access

- Excavating around steel piles to expose the section underground and level the area

Step 2: Erecting Scaffolding

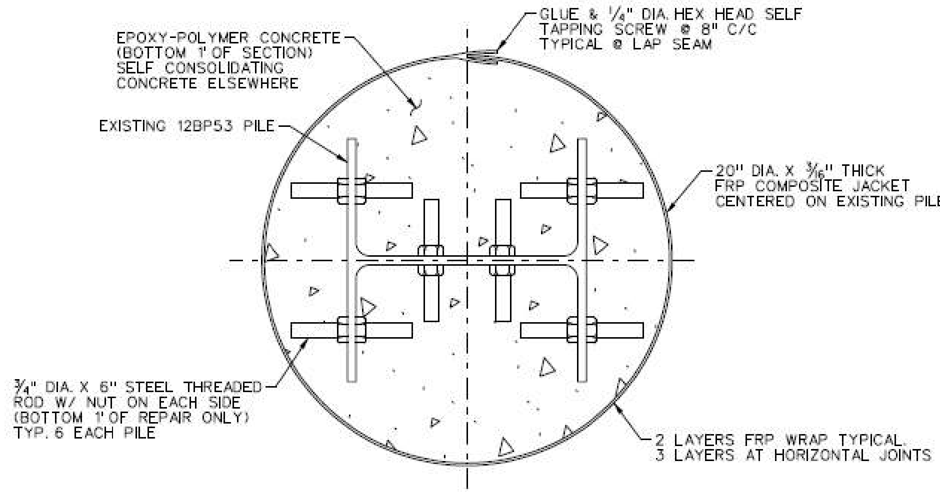
- Erecting scaffolding around the steel bents

Step 3: Pressure Washing

- Pressure washing of the piles

Step 4: Installing Shear Connectors

- Installation of shear connectors to transfer the load from the strengthened section back to un-corroded steel piles



Step 5: Installing Sensors

- Installation of sensors (strain sensors and corrosion sensors) and conduits for long term performance monitoring

Step 6: Load Testing prior to Rehabilitation

Step 7: Installing 3’ Footers

- Installation of a 3-foot long bottom shell

Step 8: Filling Bottom Shell with Polymer Concrete

- Filling bottom shell with polymer concrete as a barrier

Step 9: Building Upper Shells

Step 10: Installing Concrete Pouring Port

Step 11: Wrapping Shell with FRPs

Step 12: Pumping SCC Concrete

Step 13: Painting FRP Wraps

- Painting of the FRP wraps using water resistant UV coating

Step 14: Finishing Headers

- Removal of concrete pouring port, finish the top section wrap and painting

Step 15: Installing External Sensors

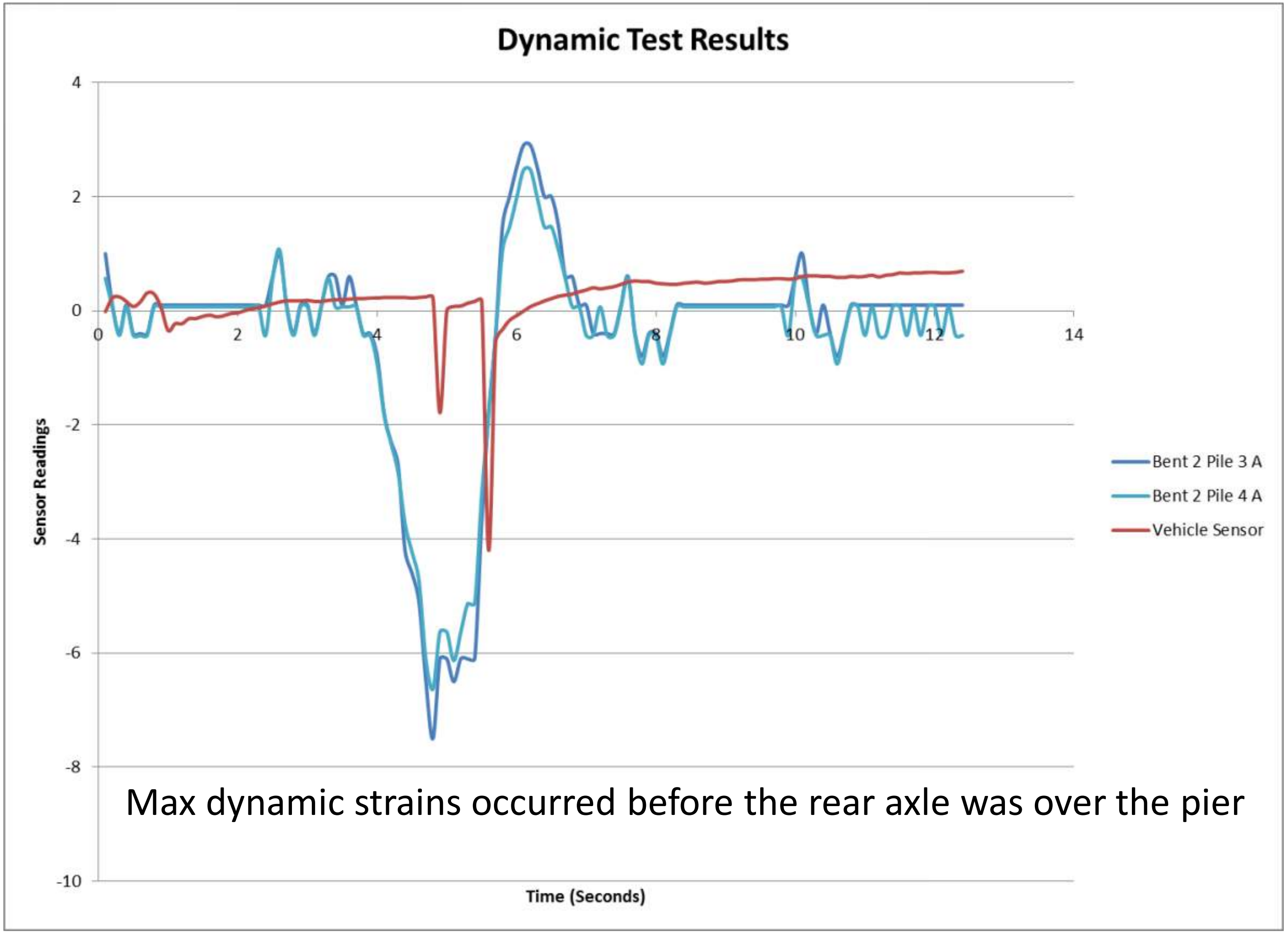
Step 16: Load Testing after Rehabilitation

Step 17: Finish up

- Removal of scaffolding, cleanup site, and backfill of gravel

East Lynn Bridge, WV
After Rehab

Sensor Readings as a Function of Time during a Dynamic Load Test



Pre- and Post- Repair Load Testing of East Lynn Lake Bridge

			Normalized Stresses (psi/kip of truck load)				Reduction	
			Static Testing		Dynamic Testing			
Sensor	Location	Type	Pre-repair	Post-repair	Pre-repair	Post-repair	Static	Dynamic
Strain 1	Bent 2 Pile 3	Beam - Axial	-19.3	-1.9	-20.6	-5.7	10%	28%
Strain 2	Bent 2 Pile 3	Beam - Axial	-20.6	-2.0	-22.8	-6.2	10%	27%
Strain 3	Bent 2 Pile 4	Beam - Axial	-16.5	-1.2	-15.1	-5.1	7%	34%
Strain 4	Bent 2 Pile 4	Beam - Axial	-17.3	-1.7	-15.8	-5.3	10%	33%
Strain 5	Bent 1 Pile 3	Beam - Axial	-11.0	-2.0	-13.1	-4.3	18%	33%
Strain 6	Bent 1 Pile 3	Beam - Axial	-11.0	-1.9	-13.1	-4.2	17%	32%
Strain 7	Bent 2 Pile 3	Wrap - Axial	N/A	-0.1	N/A	0.7	N/A	N/A
Strain 8	Bent 2 Pile 3	Wrap - Hoop	N/A	0.3	N/A	-2.7	N/A	N/A
Strain 9	Bent 2 Upstream	Concrete Cap	ND	0.4	ND	0.4	N/A	N/A
Strain 10	Bent 2 Downstream	Concrete Cap	ND	0.6	ND	0.7	N/A	N/A

- ND: Concrete cap sensors were not operational during pre-wrap test.
- Stresses computed by multiplying the averaged strains with modulus for each material.
- Normalized stresses are defined as the stresses per kip of truck load.

Before and After Repair

Conclusions

- Advanced composites were successfully used to retrofit heavily corroded steel piles and have transformed a deteriorated bridge into a new structure.
- The load tests revealed that the load carrying capacity was enhanced 10 times higher under static loads and 3 times higher under dynamic loads.
- For the past four years, the bridge has been monitored extensively for any corrosion activity of H-piles and also for its static and dynamic responses: no more corrosion.
- This work demonstrated several composite advantages: 1) design flexibility, 2) innovative, 3) rapid deployment, 4) cost-effective, 5) outstanding performance.
- Composite rehab approach offers great potential for strengthening a wide range of timber, steel, concrete structures and will play an important role in sustaining existing constructed facilities.

Questions and Discussions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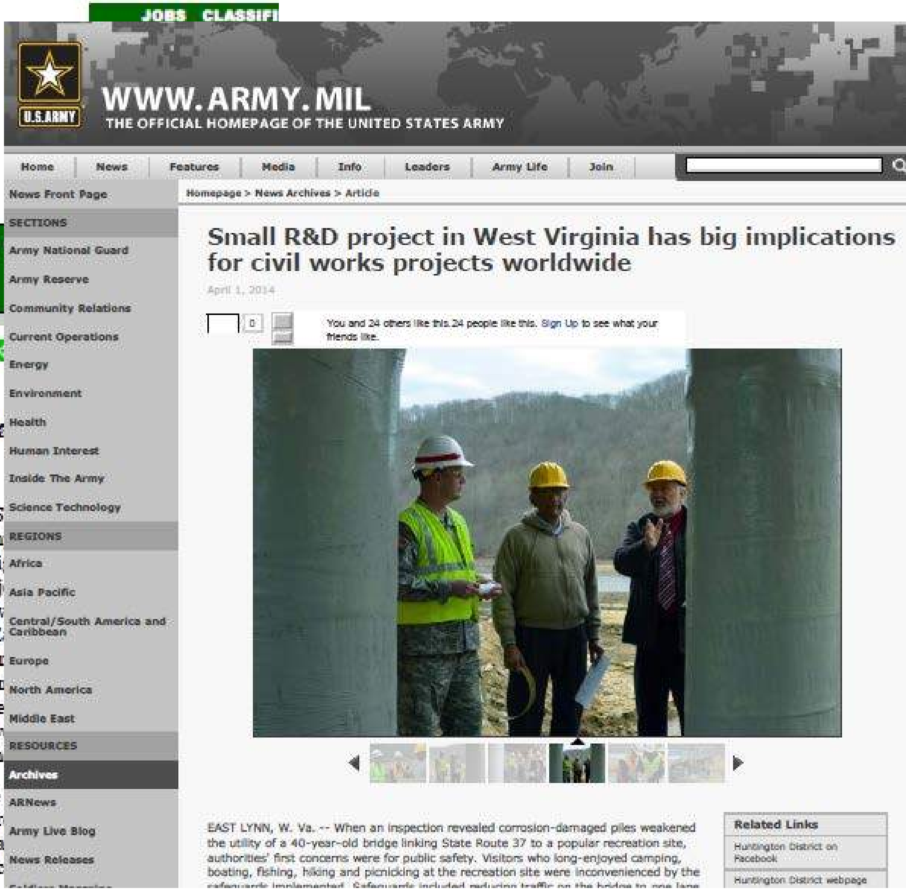
by Rick Steelhammer, Staff writer

KENNY KEMP | SUNDAY GAZETTE-MAIL

Huntington District Corps of Engineers Col. Leon F. Parrott looks at a roll of composite wrap used on the bridge piers and being held by engineering grad student Luis Parra.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